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Clinical Outcomes of Long-Pulsed 1064-nm Nd:YAG Laser Therapy for Facial Acne Scars: A Prospective Before-and-After Study

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Abstract: **Background:** Facial acne scarring is a common sequela of acne vulgaris and is frequently associated with long-term psychosocial burden. Long-pulsed 1064-nm Nd:YAG laser therapy provides deep dermal penetration with a favorable safety profile, particularly in darker skin phototypes; however, prospective real-world data remain limited. **Objective:** To evaluate within-subject changes in facial acne scar severity and treatment tolerability following long-pulsed 1064-nm Nd laser therapy in patients with Fitzpatrick skin types III and IV. **Methods:** This prospective, single-arm before-and-after study enrolled 98 adult patients with facial acne scars treated at a tertiary dermatology center. Participants received six sessions of long-pulsed 1064-nm Nd:YAG laser therapy at two-week intervals, applied unilaterally to standardize treatment exposure. Scar severity was assessed at baseline and six months after treatment using the Goodman and Baron acne scar grading system and the Scar Severity Scale (SCAR-S). Scar morphologies and treatment-related pain were also evaluated. **Results:** Following treatment, statistically significant reductions in acne scar severity were observed across both outcome measures. The median Goodman and Baron score decreased from 8.0 (IQR: 3.0) at baseline to 5.5 (IQR: 2.0) after treatment, with a median change of −2.0 (IQR: 2.0; $Z = -8.025$, $p<0.001$; effect size $r = 0.81$). The median SCAR-S score decreased from 3.0 (IQR: 2.0) to 2.0 (IQR: 1.0), with a median change of −1.0 (IQR: 1.0; $Z = -7.072$, $p<0.001$; effect size $r = 0.71$). Improvement was observed in 85.7% and 58.2% of participants according to the Goodman and Baron and SCAR-S measures, respectively. Significant score reductions were detected across all major atrophic scar subtypes, including ice-pick, boxcar, and rolling scars (all $p<0.001$). Treatment-related pain was generally mild, and no clinically evident post-inflammatory hyperpigmentation or serious adverse events were observed during routine clinical follow-up. **Conclusion:** Long-pulsed 1064-nm Nd laser therapy was associated with statistically significant reductions in facial acne scar severity and demonstrated good tolerability in patients with Fitzpatrick skin types III and IV. The observed score changes were accompanied by large statistical effect sizes; however, their clinical meaningfulness should be interpreted cautiously in the absence of an established minimally clinically important difference for the outcome measures used. Because this was an uncontrolled before-and-after study, the observed changes cannot be attributed definitively to the intervention. Controlled comparative studies are needed to establish treatment efficacy.

Key Words: Acne Scars, Nd:YAG Laser, Long-Pulsed Laser Therapy, Fitzpatrick Skin Types, Non-Ablative Laser

INTRODUCTION

Acne vulgaris is a common chronic inflammatory dermatosis affecting adolescents and young adults, frequently leading to permanent facial scarring [1]. Acne scars represent a persistent therapeutic challenge and are associated with a substantial psychosocial burden, including reduced self-esteem, social avoidance, and impaired quality of life [2,3]. Despite the benign nature of the disease itself, its long-term cosmetic and psychological consequences underscore the importance of developing effective, safe, and accessible treatment strategies for acne scarring [4].

Multiple therapeutic modalities have been employed in the management of acne scars, including chemical peeling, dermabrasion, subcision, microneedling, and laser-based interventions [5–7]. Among these, laser technologies have gained increasing attention due to their ability to induce

dermal remodeling through controlled thermal stimulation while minimizing injury to surrounding tissues [8]. Non-ablative laser systems, in particular, offer the advantages of shorter recovery periods and improved safety profiles compared with ablative techniques, making them suitable for patients seeking minimally invasive procedures [9].

The long-pulsed neodymium-doped yttrium aluminum garnet (Nd:YAG) laser, operating at a wavelength of 1064 nm, is characterized by relatively deep dermal penetration and low absorption by epidermal melanin [10,11]. These properties allow targeted photothermal stimulation of collagen remodeling while reducing epidermal injury and the risk of post-inflammatory pigmentary alterations [12]. Consequently, long-pulsed Nd:YAG laser therapy is considered particularly appropriate for individuals with darker skin phototypes, who are more susceptible to pigmentary complications following cosmetic procedures [13].

Several studies have reported clinical improvement in atrophic acne scars following treatment with long-pulsed or non-ablative Nd:YAG lasers, suggesting potential benefits in scar texture and severity reduction [14,15]. However, the existing literature remains heterogeneous in terms of study design, laser parameters, outcome measures, and follow-up duration. Many investigations include mixed laser modalities, small sample sizes, or predominantly lighter skin phototypes, which limits the generalizability of findings [16]. Furthermore, few studies have systematically evaluated responses according to acne scar morphology using validated grading systems in routine clinical practice.

In the Kurdistan Region of Iraq, acne scarring is encountered in dermatologic practice. To our knowledge, no published prospective studies from Iraq or the Kurdistan Region have specifically evaluated long-pulsed 1064-nm Nd:YAG laser therapy for acne scarring, including among patients with Fitzpatrick skin types III and IV. The present study was designed to contribute to this evidence by prospectively evaluating a standardized six-session long-pulsed 1064-nm Nd:YAG protocol in patients with Fitzpatrick skin types III and IV, using two clinical scar-grading systems and separate assessment of ice-pick, boxcar, and rolling scar morphologies, with outcomes assessed six months after completion of treatment. This provides region-specific real-world data while maintaining a clearly defined laser modality and treatment protocol.

This study was designed to assess temporal clinical changes within treated facial areas rather than to establish comparative efficacy against untreated controls. Secondary objectives included assessment of treatment response across different scar morphologies and exploration of associations between clinical outcomes and patient-related factors among patients attending the Erbil Dermatology Teaching Center.

METHODS

Study Design and Setting

This prospective, single-arm, before-and-after clinical study was conducted at the Erbil Dermatology Teaching Center, Erbil, Kurdistan Region of Iraq. The center is a specialized tertiary dermatology teaching facility providing outpatient dermatologic services and receiving patients requiring specialized dermatologic assessment and treatment. The study was designed to evaluate within-subject changes in acne scar severity following treatment and did not include a control or comparator group; therefore, it was not designed to establish comparative treatment efficacy.

Study Population

No formal a priori sample-size calculation was performed. The sample consisted of eligible patients consecutively recruited during the predefined study period who agreed to participate and fulfilled the study eligibility criteria.

A total of 124 patients with clinically diagnosed facial acne scars were assessed for eligibility at the outpatient dermatology clinics between June 2024 and September 2025. Of these, 14 patients did not meet the eligibility criteria. All 110 patients who met the eligibility criteria were approached consecutively and invited to participate; 12 declined participations, and the remaining 98 provided written informed consent and were enrolled in the study. All 98 participants completed the six treatment sessions and the six-month post-treatment assessment and were included in the final analysis.

Inclusion Criteria

- Age ≥18 years
- Presence of clinically evident facial atrophic acne scars, including ice-pick, boxcar, and/or rolling scar morphology
- No acne scar treatment within the preceding 6 months

Exclusion Criteria

- Age <18 years
- Severe active inflammatory/nodulocystic acne requiring active medical management at the time of enrollment
- Pregnancy or breastfeeding
- Immunosuppression
- History of malignancy
- Use of topical acne therapies within 1 month prior to enrollment
- Laser or light-based facial procedures within 6 months prior to enrollment
- Refusal to participate

The presence of residual inflammatory acne was assessed clinically before enrollment; however, residual acne activity was not quantified using a standardized acne-severity scale.

Scar Assessment Before Enrollment

Before enrollment, patients underwent clinical examination to confirm the presence and morphology of facial atrophic acne scars. Scar severity was subsequently documented at

baseline using the Goodman and Baron acne scar grading system and the Scar Severity Scale (SCAR-S). The study focused on atrophic acne scar morphologies (ice-pick, boxcar, and rolling scars).

Previous Acne-Scar Treatment

Previous acne-scar treatment was recorded as a history of any prior scar-directed treatment. Patients who had received acne-scar treatment within the preceding six months were excluded. For participants reporting treatment more than six months before enrollment, detailed information regarding treatment modality, timing beyond the six-month eligibility threshold, and number of previous treatment sessions was not systematically recorded.

Laser Treatment Protocol

All participants were treated using a long-pulsed Nd:YAG laser operating at a wavelength of 1064 nm. Laser treatment was applied unilaterally to the left side of the face in all participants to standardize treatment delivery and minimize procedural variability.

Laser therapy was intentionally limited to one facial side to ensure consistent exposure to standardized parameters across all participants. The primary objective of this study was to evaluate longitudinal changes within the treated area using validated scar severity scales, rather than to perform a split-face comparative analysis. The untreated contralateral side was not clinically graded or systematically documented during the study and therefore could not be included in quantitative analysis. Because assessment of the contralateral side was not incorporated into the original study protocol, comparable baseline and follow-up measurements were not available for a valid within-patient comparative analysis. Accordingly, the untreated contralateral facial side was not considered a comparator, and the analysis was confined exclusively to within-subject temporal changes on the treated side.

Laser parameters were standardized as follows:

- **Wavelength:** 1064 nm
- **Pulse Mode:** long-pulsed
- **Spot Size:** 6 mm
- **Fluence:** 10 J/cm²
- **Number of Passes:** 6

The fluence of 10 J/cm² and six passes per session reflected the standardized clinical protocol used at the study center. These parameters were applied consistently to all participants, irrespective of Fitzpatrick skin type (III or IV), baseline scar severity, or scar morphology. No participant-specific adjustment of fluence or number of passes was made as part of the study protocol.

Outcome Assessment

Clinical evaluation was performed at baseline (prior to the first laser session) and six months after completion of the final treatment session. No formal interim scar-severity assessments were performed during the treatment course or immediately after completion of the sixth treatment session.

Scar severity on the treated (left) facial side was assessed using two validated clinical grading systems:

- Goodman and Baron acne scar grading system [17]
- Scar Severity Scale (SCAR-S) [18]

Acne scar morphologies (ice-pick, boxcar, and rolling scars) were assessed separately to explore subtype-specific changes. Pain experienced during each laser session was evaluated immediately post-procedure using the Visual Analog Scale (VAS) [19].

Treatment-related adverse events were assessed clinically during treatment visits and follow-up. However, apart from pain assessment using the VAS, adverse events were not evaluated using a predefined standardized grading scale. Therefore, safety findings other than pain were based on routine clinical observation. All baseline and six-month post-treatment scar assessments were performed by the same dermatologist within the same clinical setting and under standardized evaluation conditions to maintain consistency in outcome assessment. The dermatologist was not blinded to treatment exposure or assessment time point. No formal intra-rater reliability assessment was performed. In addition, standardized photography, three-dimensional imaging, profilometry, or other objective scar-measurement techniques were not used to independently quantify treatment-associated changes. Consequently, observer and measurement bias cannot be excluded.

Statistical Analysis

Statistical analyses were conducted using appropriate statistical software. Continuous variables were expressed as median (interquartile range (IQR), while categorical variables were presented as frequencies and percentages. The Wilcoxon signed-rank test was used to compare pre- and post-treatment scar severity scores. For the three scar morphology comparisons (ice-pick, boxcar, and rolling scars), a Bonferroni correction was applied to account for multiple testing, resulting in an adjusted significance threshold of $p<0.0167$ (0.05/3). Spearman's rank correlation was applied to examine associations between baseline scar severity and patient-related continuous variables. In accordance with the secondary study objectives, prespecified exploratory analyses examined associations between scar severity outcomes and patient-related factors. Age, duration of acne scarring, and duration of prior acne treatment were examined in relation to baseline SCAR-S and Goodman and Baron scores using Spearman's rank correlation. Post-treatment SCAR-S and Goodman and Baron scores were compared according to sex, family history of acne scarring, previous acne scar treatment, and Fitzpatrick skin type (III versus IV) using the Mann–Whitney U test. No adjustment for multiple comparisons was applied to these exploratory analyses; therefore, the resulting p-values were considered

nominal and were interpreted cautiously. Effect sizes for within-subject changes were calculated as $r = |Z|/\sqrt{N}$, where Z represents the standardized Wilcoxon test statistic and N represents the number of paired observations. A p-value<0.05 was considered statistically significant.

Ethical Considerations

Ethical approval was obtained from the Research Ethics Committee of college of medicine, Hawler Medical University. All procedures were conducted in accordance with the Declaration of Helsinki, and written informed consent was obtained from each participant prior to study participation.

RESULTS

Participant Characteristics

A total of 98 patients with facial acne scars were included in the analysis. The median age of participants was 23 years (IQR: 7), and the median duration of acne scarring was 4 years (IQR: 2.25). The median duration of prior acne treatment was 5.5 months (IQR: 6).

Female patients comprised the majority of the sample (70.4%), while 29.6% were male. With respect to skin phototype, 56.1% of participants had Fitzpatrick skin type III and 43.9% had type IV. A family history of acne scarring was reported by 50% of participants, and most patients (83.7%) had not received any previous acne scar treatment.

Pain during laser treatment was generally mild, with most patients reporting Visual Analog Scale (VAS) scores of 1 or 2 (71.4%), indicating good tolerability of the procedure (Table 1).

No clinically evident post-inflammatory hyperpigmentation, scarring, infection, or prolonged erythema was observed during the follow-up period.

Treatment Tolerability and Adverse Events

Treatment-related pain was generally mild, with VAS scores ranging from 1 to 4. No clinically evident post-inflammatory hyperpigmentation or serious treatment-related adverse events were observed during routine clinical follow-up. However, adverse events other than pain were not systematically graded using a standardized assessment scale.

Table 1: Demographic and Clinical Characteristics of the Study Participants (N = 98)

Variable	Category/Statistic	Value
Age (years)	Median (IQR)	23 (7)
Duration of acne scars (years)	Median (IQR)	4 (2.25)
Duration of prior acne treatment (months)	Median (IQR)	5.5 (6)
Sex	Male	29 (29.6%)
	Female	69 (70.4%)
Fitzpatrick skin type	Type III	55 (56.1%)
	Type IV	43 (43.9%)
Family history of acne scars	Negative	49 (50.0%)
	Positive	49 (50.0%)
Previous acne scar treatment	No	82 (83.7%)
	Yes	16 (16.3%)
VAS pain score	1	25 (25.5%)
	2	45 (45.9%)
	3	23 (23.5%)
	4	5 (5.1%)

Continuous variables are presented as median (interquartile range [IQR]); categorical variables are presented as *n* (%). VAS, Visual Analog Scale

Table 2: Comparison of Scar Severity Scores on the Treated Facial Side Before and After Laser Therapy (N = 98)

Outcome measure	Baseline Median (IQR)	Post-treatment Median (IQR)	Median Change (IQR)‡	Negative Ranks n (%)†	Positive Ranks n (%)¶	Ties n (%)	Z value	p-value	Effect Size (r)§
Goodman and Baron score	8.0 (3.0)	5.5 (2.0)	−2.0 (2.0)	84 (85.7%)	0 (0.0%)	14 (14.3%)	−8.025	<0.001	0.81
SCAR-S score	3.0 (2.0)	2.0 (1.0)	−1.0 (1.0)	57 (58.2%)	0 (0.0%)	41 (41.8%)	−7.072	<0.001	0.71

† Negative ranks indicate that the post-treatment score was lower than the baseline score. A negative rank represents any numerical score reduction and does not indicate achievement of a predefined clinically meaningful response threshold, ¶ Positive ranks indicate that the post-treatment score was higher than the baseline score, reflecting worsening. No positive ranks were observed for either outcome measure, ‡ Change was calculated as post-treatment minus baseline; therefore, negative values indicate improvement, § Effect size was calculated as $r = |Z|/\sqrt{N}$. Values are presented as median (interquartile range (IQR) or *n* (%), as appropriate

Table 3: Changes in Acne Scar Subtype Counts on the Treated Facial Side Before and Six Months After Laser Therapy (N = 98)

Scar type	Baseline Median (IQR)	Post-treatment Median (IQR)	Median Change (IQR)	Z value	P value	Effect size (r)
Ice-pick scars	13.0 (6.0)	10.0 (5.0)	−3.0 (3.0)	−8.319	<0.001	0.84
Boxcar scars	3.0 (4.0)	2.0 (3.75)	0.0 (1.75)	−6.079	<0.001	0.61
Rolling scars	5.0 (4.0)	4.0 (3.0)	−1.0 (2.0)	−7.099	<0.001	0.72

Values represent the number of scars of each morphology on the treated facial side and are presented as median (interquartile range (IQR). Change was calculated as post-treatment minus baseline; negative values indicate a reduction in scar count. Comparisons were performed using the Wilcoxon signed-rank test. Effect size was calculated as $r = |Z|/\sqrt{N}$. A Bonferroni-adjusted significance threshold of p<0.0167 (0.05/3) was applied to account for the three scar morphology comparisons

Table 4: Correlation Between Patient Factors and Baseline Scar Severity Scores (N = 98)

Predictor variable	SCAR-S (ρ)	p-value	Goodman and Baron (ρ)	p-value
Age (years)	−0.18	0.074	−0.15	0.148
Scar duration (years)	−0.35	<0.001*	−0.05	0.619
Acne treatment duration (months)	−0.01	0.919	0.10	0.306

ρ denotes Spearman's rank correlation coefficient. These analyses were exploratory and were not adjusted for multiple comparisons; therefore, the reported p-values are nominal and should be interpreted cautiously, *Nominally statistically significant at p<0.05

Table 5: Factors Associated with Post-Treatment Scar Severity on the Treated Facial Side (N = 98)

Influencing factor	Outcome measure	Group 1 Median (IQR)	Group 2 Median (IQR)	Z value	*p*-value
Gender	SCAR-S	Male: 3.0 (1.0)	Female: 2.0 (2.0)	−1.323	0.186
	Goodman and Baron	Male: 5.0 (2.0)	Female: 6.0 (2.0)	−0.517	0.605
Family history of acne scars	SCAR-S	Negative: 2.0 (2.0)	Positive: 2.0 (1.0)	−0.295	0.768
	Goodman and Baron	Negative: 5.0 (2.0)	Positive: 6.0 (2.0)	−0.022	0.983
Previous acne scar treatment	SCAR-S	No: 2.0 (1.0)	Yes: 2.0 (1.25)	−0.032	0.975
	Goodman and Baron	No: 6.0 (2.0)	Yes: 5.0 (2.0)	−0.295	0.768
Fitzpatrick skin type	SCAR-S	Type III: 2.0 (2.0)	Type IV: 3.0 (1.0)	−2.533	0.011*
	Goodman and Baron	Type III: 5.0 (2.0)	Type IV: 6.0 (2.0)	−1.398	0.162

Values are presented as median (interquartile range (IQR). Between-group comparisons were performed using the Mann–Whitney U test. These analyses were exploratory and were not adjusted for multiple comparisons; therefore, the reported *p*-values are nominal and should be interpreted cautiously, *Nominally statistically significant at $p<0.05$

Overall Treatment Outcomes

Following six sessions of long-pulsed 1064-nm Nd:YAG laser therapy, a statistically significant reduction in acne scar severity on the treated (left) facial side was observed.

Using the Goodman and Baron acne scar grading system, 84 participants (85.7%) demonstrated a reduction in post-treatment scores, while 14 (14.3%) showed no change. The median Goodman and Baron score decreased from 8.0 (IQR: 3.0) at baseline to 5.5 (IQR: 2.0) after treatment, corresponding to a median change of −2.0 (IQR: 2.0). These proportions represent participants with any numerical reduction in score and should not be interpreted as the proportion achieving a predefined clinically meaningful treatment response.

Similarly, SCAR-S scores decreased in 57 participants (58.2%), with 41 participants (41.8%) showing unchanged scores. The median SCAR-S score decreased from 3.0 (IQR: 2.0) at baseline to 2.0 (IQR: 1.0) after treatment, with a median change of −1.0 (IQR: 1.0).

Wilcoxon signed-rank testing confirmed statistically significant reductions in both outcome measures (Goodman and Baron: $Z = -8.025$, $p<0.001$, $r = 0.81$; SCAR-S: $Z = -7.072$, $p<0.001$, $r = 0.71$), with both measures demonstrating large statistical effect sizes (Table 2).

Scar Type–Specific Outcomes

Analysis of acne scar subtypes on the treated facial side demonstrated statistically significant reductions across all evaluated morphologies. The numbers of ice-pick, boxcar, and rolling scars decreased significantly from baseline to the six-month post-treatment assessment (all $p<0.001$). These findings represent reductions in the recorded number of scars within each morphology rather than uniform or complete resolution of individual scars (Table 3).

Associations Between Baseline Scar Severity and Patient Factors

Spearman's rank correlation analysis showed a moderate negative correlation between scar duration and baseline SCAR-S scores (Spearman's $\rho = -0.35$, $p<0.001$). No statistically significant correlations were observed between age or duration of prior acne treatment and baseline SCAR-S or Goodman and Baron scores (Table 4).

Factors Associated with Post-Treatment Outcomes

Exploratory analyses showed a nominally statistically significant difference in post-treatment SCAR-S scores according to Fitzpatrick skin type, with higher median scores among participants with type IV skin than among those with type III skin [3.0 (IQR 1.0) vs 2.0 (IQR 2.0), respectively; $p = 0.011$]. No statistically significant differences in post-treatment SCAR-S or Goodman and Baron scores were observed according to gender, family history of acne scarring, or previous acne scar treatment. The Goodman and Baron score also did not differ significantly between Fitzpatrick skin types ($p = 0.162$) (Table 5). These analyses were exploratory and were not adjusted for multiple comparisons; therefore, the findings should be interpreted cautiously.

DISCUSSION

The findings of the present study are broadly consistent with recent evidence supporting the clinical utility of 1064-nm Nd:YAG laser–based modalities for post-acne scar management [20,21]. In particular, our observation of statistically significant reductions in acne scar severity after multiple sessions of long-pulsed 1064-nm Nd:YAG laser therapy aligns with outcomes reported in international studies using similar wavelength platforms [22–24]. In the present study, these reductions were accompanied by large statistical effect sizes for the primary outcome measures; however, the clinical significance of these changes cannot be established because a predefined minimal clinically important difference was not used. Although ice-pick scars are classically considered less responsive to non-ablative laser modalities [25], the statistically significant reductions observed in scar counts likely reflect partial improvement

rather than complete resolution of this scar morphology. The magnitude of treatment-associated change may therefore differ across scar subtypes despite overall statistical significance.

Pratiwi *et al.* reported significant improvement in acne scar severity following long-pulsed 1064-nm Nd:YAG laser therapy combined with topical vitamin C application. Although their study incorporated an adjunctive topical agent and differed in outcome measures, the direction of clinical improvement parallels our findings, suggesting that long-pulsed Nd:YAG laser–induced dermal remodeling contributes meaningfully to scar improvement regardless of minor protocol variations [26]. The present study extends this evidence by demonstrating improvement using laser therapy alone and by employing validated clinical grading systems.

More recently, Park *et al.* evaluated Q-switched 1064-nm Nd:YAG laser therapy with a multi-depth focusing hand piece for acne scars and reported favorable clinical outcomes with minimal downtime and good tolerability [27]. Their findings support the safety and effectiveness of Nd:YAG-based approaches and are consistent with our observation of significant scar severity reduction and good tolerability. While Park *et al.* included a Q-switched modality, our study specifically contributes prospective data on a standardized long-pulsed protocol, reinforcing its clinical relevance in routine practice.

Advances in Nd:YAG laser delivery systems have also been explored through fractional and picosecond technologies. A prospective randomized split-face study comparing fractional 1064-nm Nd:YAG picosecond laser with ablative fractional 2940-nm Er:YAG laser demonstrated significant improvement in atrophic acne scars, with comparable efficacy between modalities and a more favorable safety profile for the Nd:YAG system, including lower pain scores and reduced post-inflammatory hyperpigmentation [28]. Although picosecond fractional Nd:YAG lasers differ mechanistically from long-pulsed systems, both approaches rely on controlled dermal injury to stimulate collagen remodeling. The consistency of clinical improvement and favorable tolerability across these distinct Nd:YAG platforms supports the biological plausibility of the scar severity reductions observed in the present long-pulsed Nd:YAG study.

Advances in Nd:YAG laser delivery systems have also been explored through fractional and picosecond technologies. A prospective study evaluating a fractional 1064-nm picosecond Nd:YAG laser demonstrated significant clinical improvement in atrophic acne scars with a favorable safety profile and minimal downtime [29]. Objective clinical assessments in that study showed reductions in scar severity and skin surface irregularity, supporting effective dermal remodeling despite differences in pulse duration and delivery format. Although picosecond fractional systems differ from long-pulsed Nd:YAG lasers in energy deposition and pulse width, both approaches rely on controlled dermal injury to stimulate collagen remodeling. Collectively, these findings suggest that diverse Nd:YAG-based technologies may converge on similar remodeling pathways, albeit through different treatment dynamics, reinforcing the biological plausibility of the improvements observed in the present long-pulsed Nd:YAG study.

Recent investigations have also explored the use of Nd:YAG-based technologies for post-acne skin changes beyond scar texture. A 2023 study evaluating a fractional 1064-nm Nd:YAG/picosecond laser approach for post-acne erythema reported significant reductions in residual erythema with a favorable safety profile and minimal adverse effects [30]. Although *post-acne erythema* and *atrophic scarring* represent distinct sequelae of acne, these findings illustrate the versatility of Nd:YAG-based modalities in improving multiple components of acne-affected skin. The ability of these laser systems to attenuate vascular and inflammatory features, as well as to stimulate dermal remodeling, further contextualizes the clinical relevance of our long-pulsed 1064-nm Nd:YAG results in acne scar severity and supports the broader therapeutic potential of Nd:YAG platforms in comprehensive acne sequelae management.

Narrative syntheses of contemporary acne scar management further support the role of energy-based devices. Attia reviewed current approaches to atrophic acne scar treatment and identified Nd:YAG laser systems among both established and emerging modalities with documented therapeutic value [14]. This narrative synthesis places the present study within a growing body of evidence supporting the inclusion of Nd:YAG lasers in the modern acne scar treatment armamentarium.

Collectively, recent evidence—including prospective clinical studies, device-specific investigations, and narrative reviews—demonstrates consistent trends toward clinical improvement in acne scar severity using 1064-nm Nd:YAG-based therapies [14,20,21,26]. Although methodological heterogeneity across studies limits direct quantitative comparison, the concordance in the direction of clinical outcomes across diverse Nd:YAG platforms supports the clinical relevance of the improvements observed in the present prospective study among patients with Fitzpatrick skin types III and IV.

The primary limitation of this study is the absence of a control or comparator group, which restricts causal inference. Observed improvements may reflect natural scar remodeling, placebo effects, regression to the mean, or observer-related bias. Although treatment was delivered unilaterally, the untreated contralateral facial side was not clinically graded or systematically documented and therefore could not function as an internal comparator. This represents an important missed opportunity for a within-patient split-face comparison, which could have helped distinguish treatment-associated changes from temporal changes, regression to the mean, and other non-treatment effects. Consequently, the unilateral treatment approach should not be interpreted as a controlled split-face design.

Outcome assessment relied on validated but subjective clinical grading scales without blinding, objective imaging modalities, or inter-rater reliability testing, introducing potential observer bias. Although statistically significant reductions and large statistical effect sizes were observed for the primary outcomes, the study did not use a predefined minimal clinically important difference or responder threshold. Consequently, the clinical significance of the observed score changes cannot be determined from the present data alone. Safety assessment was primarily limited to patient-reported pain, and pigmentary or subtle textural adverse effects were not graded systematically. No formal a priori sample-size calculation was performed, which limits assessment of whether the study was adequately powered, particularly for the exploratory secondary analyses. Finally, the single-center design may limit generalizability.

Future controlled studies incorporating split-face designs, objective assessment tools, predefined clinically meaningful response thresholds, and standardized adverse-event reporting are warranted.

CONCLUSION

Long-pulsed 1064-nm Nd:YAG laser therapy was associated with statistically significant reductions in facial acne scar severity scores on the treated facial side in this prospective before-and-after study. Reductions in scar counts were also observed across the major atrophic scar morphologies, and treatment-related pain was generally low among patients with Fitzpatrick skin types III and IV.

While these findings support the feasibility and potential clinical benefit of long-pulsed Nd:YAG laser therapy in routine dermatologic practice, the absence of a control group precludes definitive conclusions regarding efficacy. Furthermore, the absence of a predefined clinically meaningful response threshold limits interpretation of the clinical significance of the observed changes. Future controlled studies incorporating split-face designs, objective scar assessment tools, predefined clinically meaningful outcome thresholds, and comprehensive standardized adverse-event assessment are required.

Declarations

Ethics Approval and Consent to Participate

Ethical approval was obtained from the Research Ethics Committee of the College of Medicine, Hawler Medical University. All study procedures were conducted in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained from each participant prior to study participation.

Consent for Publication

Not applicable. This manuscript does not contain any individual person's identifiable data.

Availability of Data and Materials

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Competing Interests

The authors declare that they have no competing interests.

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Authors' Contributions

Both authors contributed substantially to the conception and design of the study. Data collection and clinical procedures were performed by the authors. Data analysis and interpretation were conducted jointly. The manuscript was drafted by the corresponding author and critically reviewed and revised by the second author. Both authors read and approved the final version of the manuscript.

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